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LIVE-BAIT FISHING FOR TUNA IN THE CENTRAL PACIFIC

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United States Department of the Interior, Douglas McKay, Secretary
Fish and Wildlife Service, John L. Farley, Director

LIVE-BAIT FISHING FOR TUNA IN THE CENTRAL PACIFIC

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Special Scientific Report: Fisheries No. 107

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INTRODUCTION

Since its inauguration in 1949 the Pacific Oceanic Fishery Investigations (POFI) of the U. S. Fish and Wildlife Service has undertaken various research projects in order to explore and develop the high-seas fishery resources of the various territories and possessions of the United States in the tropical and subtropical Pacific Ocean. One project was to conduct exploratory live-bait fishing in the central Pacific (fig. 1).

The vast area included in figure 1 at present supports only one important live-bait pole-and-line fishery -- that which is carried on in the immediate vicinity of the Hawaiian Islands. Before the investigations by POFI there were sporadic attempts to fish for tuna[1/] by the live-bait method in this area. The attempts for which information is available were by the seiner-dragger, Oregon, which was converted into a live-bait boat and which fished in the vicinity of the Line Islands (Smith and Schaefer 1949) and the main and leeward islands of the Hawaiian group (Eckles 1949) in 1948, the tuna clippers Pioneer and Calistar, which did exploratory fishing in the vicinity of the Line Islands during 1947 and 1949 respectively, and the Hawaiian sampan[2/] Tradewind, which fished for tuna at the Line Islands during January and February of 1953. The POFI vessels Hugh M. Smith and Henry O'Malley, both built along American west coast tuna clipper lines, conducted exploratory live-bait fishing for tuna in the vicinity of the Line, Phoenix, and Hawaiian islands during 1949, 1950, and 1951. This report deals primarily with the observations made on these two vessels.

1/ Yellowfin tuna (Neothunnus macropterus), skipjack (Katsuwonus pelamis), black skipjack (Euthynnus yaito), and bigeye tuna (Parathunnus sibi).

2/ The sampans (fig. 2) in use in the Hawaiian live-bait fishery during 1950 ranged in size from 65 to 92 feet overall length, the 92-footer having a gross tonnage of 77 tons. Typically a sampan is a modified V-bottomed vessel, with a narrow beam in relation to its length, straight raking stem, well developed sheer, narrow entry, and overhanging sponsons. There is no mast and boom and the vessel is generally powered by a 165 to 330 H. P. diesel engine. A pilot house with a flying bridge is located amidships, and sleeping quarters are located forward. Fishing is done from the deck at the stern of the vessel. Sampans carry no refrigeration except for some ice which is used to ice the fish down after capture. They have 2 to 6 bait wells, which have a series of screened holes on the bottom to provide circulation.

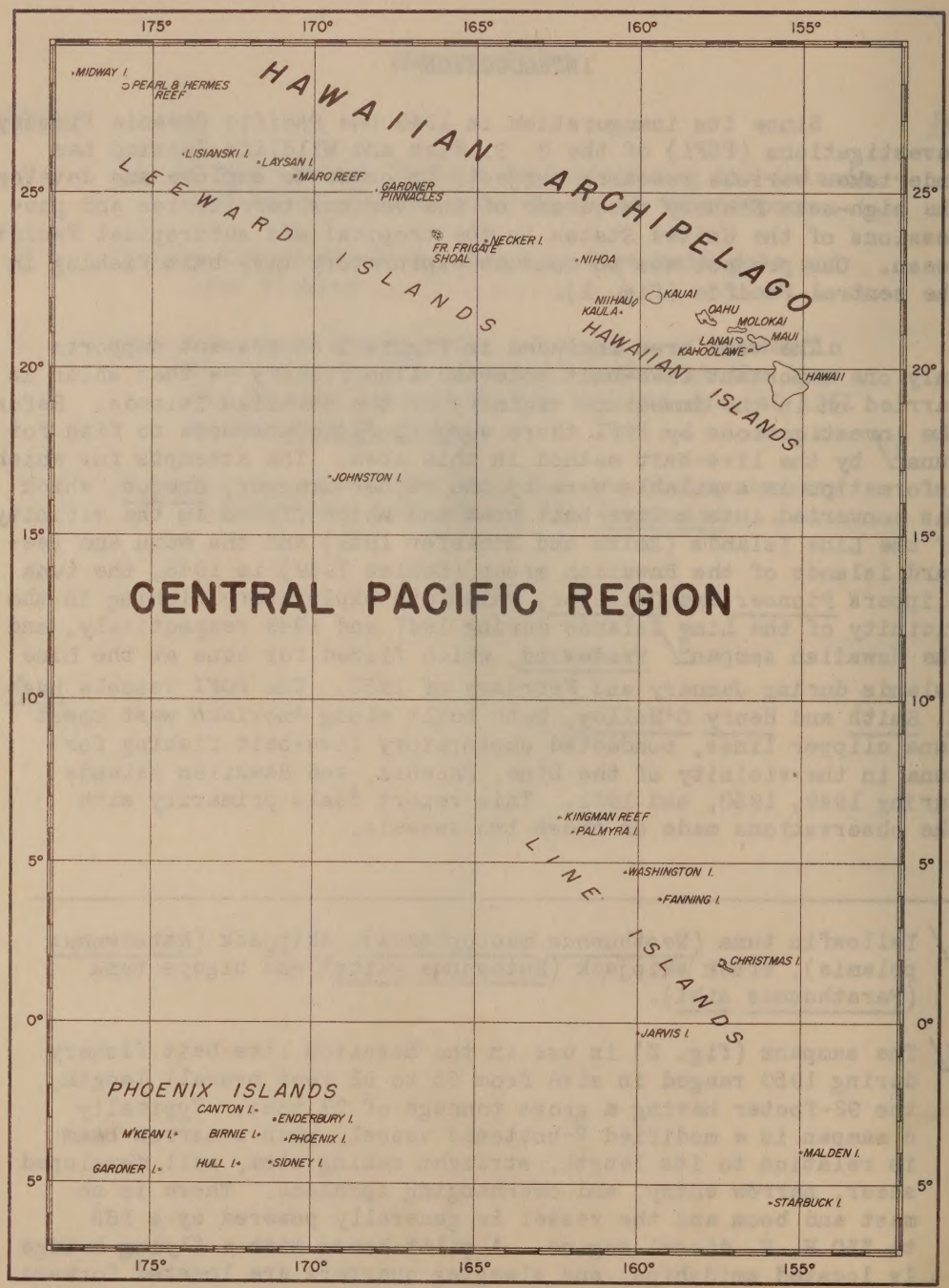

FIG. I. MAP OF THE CENTRAL PACIFIC REGION SHOWING THE ISLANDS AND ISLAND GROUPS REFERRED TO IN THIS REPORT.

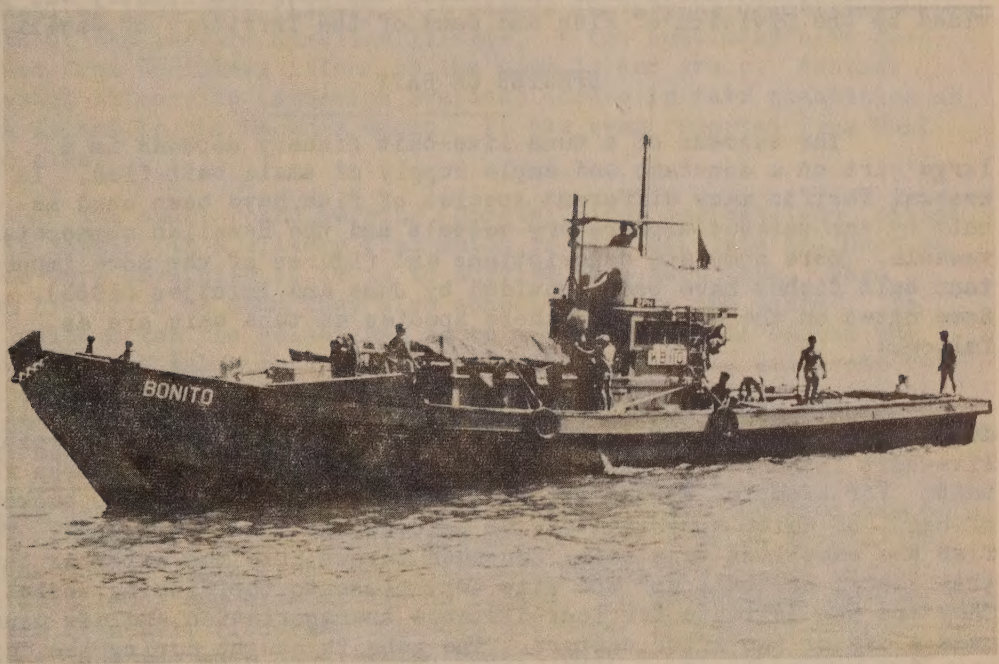

FIG. 2. A SAMPAN TYPICAL OF THE HAWAIIAN LIVE-BAIT POLE AND LINE FISHERY.

ACKNOWLEDGMENTS

Most of the data and information used in this report were extracted from the logs of field observations kept by the scientist-observers, officers, and fishermen-crew members of the POFI research vessels, Hugh M. Smith and Henry O'Malley, and the commercial vessel, Tradewind. Comparative data concerning the Hawaiian fishery was provided by the Division of Fish and Game of the Territory of Hawaii.

SPECIES OF BAIT

The success of a tuna live-bait fishery depends in a large part on a constant and ample supply of small bait fish. In the central Pacific many different species of fish have been used as bait by the various exploratory vessels and the Hawaiian commercial vessels. More complete descriptions and figures of the more important bait fishes have been provided by June and Reintjes (1953). Some notes on the utility of these species as tuna bait are as follows:

The Hawaiian anchovy (Stolephorus purpureus) is a small, delicate, translucent fish known in Hawaii as nehu. The commercial live-bait fishermen of Hawaii depend almost entirely on the nehu for bait. For example, during the year 1950 an estimated 42,000 buckets[3/] of bait, of which approximately 96 percent was nehu, were used. These fish are excellent tuna bait, for when thrown into the water as chum, they school or "ball up" and stay very close to the fishing vessel. They are too delicate for long-distance transportation and are usually used a day or two after capture. The nehu is caught during the day with beach seines and during the night with lift-nets after the fish have congregated under a submerged electric light (June 1950). To date nehu have been caught only at the main Hawaiian Islands and at none of the other regions included in this report.

The silverside (Atherina insularum) is a small fish characterized by a silvery band on the side of its body. The iao, as it is called in Hawaii, is also an excellent tuna bait and is used when available. This species when thrown into the water as chum also balls up and stays very close to the vessel. The iao is relatively hardy and if handled properly can stand long-distance transportation. Smith and Schaefer (1949) report catching iao at French Frigate Shoals,

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3/ A "bucket" of bait has been variously estimated to contain from 5-1/2 to 7 pounds of fish (nehu). These are estimates derived from several attempts to ascertain the weight of nehu contained in a typical bucket of bait by the Division of Fish and and Game, Territory of Hawaii, and by staff of the University of Hawaii Marine Laboratory.

transporting them to the Line Islands, and returning to Honolulu with the unused bait still in good condition. Thus some of the iao were kept in the bait well for approximately 20 days. They concluded that "This species is suitable for long-distance transportation if properly handled." Iao are caught primarily during the day by the use of beach seines. This is the second most important bait fish used in the Hawaiian live-bait fishery. It occurs in varying quantities throughout the leeward Hawaiian Islands. A few specimens have been reported from Christmas Island in the Line Island group. Another species of silverside (Atherina ovalaua) occurs in fair quantities at Canton Island in the Phoenix Group. It has been reported from Hull Island also.

The small round herring (Spratelloides delicatulus), called piha in Hawaii, is a silvery fish which is very delicate and must be handled very carefully if it is to survive in a bait tank. When thrown overboard as chum they also school close to the vessel. In fact, quite often the vessel has to be moved forward to expose the bait which have taken refuge under it. The piha is an excellent bait fish but like the nehu must be used very soon after capture, for it does not survive long in a bait tank. It is caught during the night by the use of a lift-net when it is congregated under a submerged light. It is reported that the piha do not sound when surrounded by a net in deep water. Because of this behavior trait the fish may be driven by swimmers into a night lift-net or into a seine during the daylight hours. This fish occurs in fair quantities at the leeward Hawaiian Islands and also at Canton Island. It is utilized by the Hawaiian live-bait fishermen but does not occur in important quantities around the main Hawaiian Islands. Only a few specimens have been taken at the Line Islands.

The mountain bass (Kuhlia sandvicensis), usually known by the Hawaiian name of aholehole, is a bright silvery fish which attains a maximum length of approximately 10 inches. At smaller sizes this species is judged a good tuna bait because of its schooling behavior when thrown overboard as chum, its ready acceptance by the tunas, and its ability to survive long-distance transportation. A minor difficulty with aholehole is that the spines frequently catch in the nets and also tend to prick the hands of the chummer. It occurs at the leeward Hawaiian Islands in large quantities. Only minor quantities of mountain bass have been caught or seen at the other regions included in this report. It is caught during the day with beach seines.

The smaller individuals of the mullet family (Mugilidae) have been used as bait whenever available. Smith and Schaefer (1949) used mullet 6 inches long to chum schools of yellowfin off Fanning Island and reported, "These mullet behaved well when used to chum up the tuna." The POFI observers aboard the Tradewind also reported that mullet caught and used in the Line Islands by the fishermen of

the Tradewind reacted favorably when thrown as chum except when weak and injured mullet (which tended to swim away from the vessel) were used. The larger mullet are not desirable as bait because they too tend to swim away from the vessel. This bait fish has been used successfully to catch tuna on many occasions and is important in the vicinity of the Line and Phoenix islands because it occurs there in fair to large quantities. M. longimanus and M. vaigiensis are the most common species of mullet caught at the Line and Phoenix islands. These species have not been reported from either the main or leeward Hawaiian Islands. The most common species of mullet caught at the main and leeward Hawaiian Islands are the M. cephalus and N. chaptalii. Mullet are available at the leeward islands, but they are of no importance there because of the greater availability of other more desirable species of bait. They are not used in the Hawaiian live-bait fishery because of their high market value. The mullets are relatively hardy and can stand long-distance transportation. They can be caught readily by the use of beach seines during the daylight hours.

The smaller individuals of the goatfish family (Mullidae), especially of the genus Mulloidichthys, have been used as chum whenever available. It is characteristically a shallow-water fish which feeds on organic material that it stirs up from the bottom with its barbels. The weke, as the Hawaiians call it, is usually bright in color. At times it occurs in fair quantities along the beaches of most of the leeward Hawaiian Islands, and in the Line and Phoenix area. In Hawaii the weke is not used as chum because, like the mullets, it has a good market value. The reports on the behavior of the weke when used as chum in tuna fishing are conflicting. Some observers report that they school properly on the surface around the vessel, while others report that they sound. If sounding is the typical behavior of the weke, it will be of only limited use in live-bait fishing. This fish is relatively hardy and can stand long-distance transportation. It is caught during the day by the use of beach seines.

The top minnows (Mollienesia sp.) have been used as tuna bait by the Hawaiian fishermen in times of shortage of the more desirable bait fish such as the nehu and iao. The top minnows (also known as "mollies") are small fishes which occur in fair quantities in the streams and estuaries of some of the main Hawaiian Islands, where they are caught with seines. These fish were originally introduced into Hawaii from the American mainland to combat mosquitoes. The mollies are not an ideal tuna bait because of their tendency to sound when thrown into the water as chum.

THE BAIT RESOURCES

The bait resources of the main Hawaiian Islands appear to be fully exploited by the present commercial fleet. In 1950, a fairly typical year, 27 live-bait pole-and-line sampans caught approximately 42,000 buckets of bait. Probably more would have been

used if it were available, for during most years difficulty in obtaining bait limits the tuna catch, particularly during the height of the season. POFI experience in the Hawaiian Islands, as detailed in table 1, cannot be used as a measure of relative abundance because the most productive baiting areas fished by the commercial fleet were generally avoided.

The leeward islands of the Hawaiian chain may contain substantial supplies of bait that are not presently utilized. Baiting operations by the POFI vessels Smith and O'Malley during 1949, 1950, and 1951 indicate that the best baiting may be expected at Midway Island (table 1). French Frigate Shoals[4/] may also be a promising baiting site, for the Oregon fishing there during January (Smith and and Schaefer 1949) and August (Eckles 1949) of 1948 caught approximately 1,315 scoops[5/] of iao in about 15 days of baiting there. POFI baiting operations at French Frigate Shoals (table 1) were not as successful as those of the Oregon.

The results of baiting operations by POFI vessels at the Line Islands have been only moderately successful (table 1). Both the Oregon and the Calistar were unable to get any appreciable amount of bait there either. The Calistar was reported to have obtained only 8 scoops of bait-size mullet at Palmyra and the Oregon only 30 scoops of 6-inch mullet at Christmas Island. During the latter part of 1947 the Pioneer was reported to have caught 400 scoops of mullet at Palmyra and another 200 scoops at Christmas Island. The sampan Tradewind, fishing in the vicinity of the Line Islands during January and February of 1953, caught bait-size mullet as follows: 242 buckets at Palmyra, 85 buckets at Fanning Island, and 19 buckets at Christmas Island. Actually only a limited number of observations on the bait supply at the Line Islands have been made. Christmas Island, with a circumference of 105 miles, is one of the largest atolls in the world and the few observations and attempts at baiting made there have not adequately sampled this site. One scouting expedition in June of 1951 to the lagoon at Fanning Island located only a few schools of aholehole, but during February 1953 the Tradewind was able to catch an adequate supply of mullet without any trouble. Past experience has shown that the catchable bait at Palmyra Island is usually exhausted after only a few days of baiting. The other islands and reefs of the Line group do not appear to be suitable baiting sites either because of an insufficient bait supply or because of the difficulty of landing.

4/ Owing to bad weather during January and February of 1950, only 6 out of 18 days were such that any bait fishing or scouting could be done.

5/ A scoop is estimated to contain about 10 pounds of fish (Smith and Schaefer 1949).

Table 1.--Results of baiting operations by POFI in the central Pacific.

Locality	Date	Number of days 1/	Number of sets		Catch (by buckets)		Species of bait	
			Beach seine	Night lift-net	Beach seine	Night lift-net	Beach seine	Night lift-net
Hawaii, leeward islands:								
French Frigate Shoals	Jan. 1950; Feb. 1950; May 1950 and 1951; June 1950; July 1950.	21	11	14	57	20	65% iao 25% aholehole 10% mullet	100% piha
Laysan I.	May 1951: June 1950;	2	0	0	0	0	-	-
Lisianski I.	May 1951; June 1950.	2	10	0	83	0	88% aholehole 12% iao	-
Pearl and Hermes Rf.	May 1951; June 1950;	2	0	1	-	0	-	-
Midway I.	May 1951; June 1950; July 1950.	12	56	7	974	42	58% aholehole 17% weke 14% piha 9% iao 2% mullet	100% piha
	Total:	39	77	22	1,114	62	58% aholehole 15% weke 13% piha 12% iao 2% mullet	100% piha
Hawaii, main islands:								
Oahu	May 1950; Nov. 1949; Dec. 1949.	6	8	4	136	34	96% mollies 4% nehu	100% nehu
Maui	May 1950; June 1950; Nov. 1949; Dec. 1949.	8	16	5	100	0	58% nehu 42% iao	-
Hawaii	June 1950; Nov. 1949; Dec. 1949.	8	1	6	0	10	-	100% nehu
Molokai	May 1950.	3	4	0	63	0	100% iao	-
Lanai	May 1950.	1	0	1	0	0	-	-
Kauai	May 1950.	3	0	1	0	0	-	-
Niihau	May 1950.	1	0	1	0	0	-	-
	Total:	30	29	18	299	44	44% mollies 35% iao 21% nehu	100% nehu

1/ This includes only days or nights when bait fishing and/or scouting was carried on.

Table 1.--Results of baiting operations by POFI in the central Pacific. (Cont'd.)

Locality	Date	Number of days 1/	Number of sets		Catch (by buckets)		Species of bait	
			Beach seine	Night lift-net	Beach seine	Night lift-net	Beach seine	Night lift-net
Line Islands:								
Palmyra Island	June 1951; August 1950.	2	5	1	115	0	100% mullet	-
Christmas Island	June 1951.	1	5	0	52	-	100% mullet	-
Kingman Reef	August 1950.	1	0	1	-	0	-	-
Fanning Island	June 1951.	1	0	0	-	-	-	-
	Total:	5	10	2	167	0	100% mullet	-
Phoenix Islands:								
Canton Island	Feb. 1950; June 1951; July 1950; August 1950.	18	47	8	570	0	Majority weke and mullet. Others - iao, piha, snapper, and bonefish.	-
Hull Island	July 1950, Aug. 1950.	2	0	1	-	0	-	-
Birnie Island	August 1950.	1	0	1	-	0	-	-
Enderbury Island	August 1950.	1	0	1	-	0	-	-
Gardner Island	June 1951.	1	0	0	-	-	-	-
	Total:	23	47	11	570	0	Majority weke and mullet	-

1/ This includes only days or nights when bait fishing and/or scouting was carried on.

The only likely baiting site in the Phoenix Islands is at Canton Island (table 1), where a sizable fish population is found in the lagoon. Besides the mullet and weke which comprised the major portions of the bait catch there, some piha and iao have been caught. Good-sized schools of small mullet have been observed in the shoal parts of the lagoon. Baiting in this lagoon is made hazardous by the presence of coral heads. These also form barriers in places and prevent access into certain areas with a bait skiff and bait receiver. (This is generally true of most of the lagoons discussed.) There were no baiting operations except for a few sporadic night light and scouting attempts conducted at the other islands of the Phoenix group, for very few fish of suitable size were observed there, and also landing was very difficult except during low tide and calm weather.

In general there appear to be at least moderate supplies of unutilized bait in some of the Line, leeward Hawaiian, and Phoenix islands. These supplies do not appear adequate for the West Coast tuna clipper type of operation. They might supply a limited number of small live-bait boats like those used in the Hawaiian fishery, especially if techniques and gear were devised to capture bait in the very shoal and hazardous areas of the lagoons. Furthermore, it should be realized that the bait resources of these areas (excluding Hawaii) are virtually not utilized at present and the effect of exploitation on the stocks cannot be predicted.

TUNA FISHING WITH LIVE BAIT

The POFI program of live-bait fishing in the central Pacific was designed primarily to provide a rough evaluation of the surface tuna resources in the various regions of the central Pacific and their amenability to harvest by this method. POFI fishing in the vicinity of the Hawaiian Islands, where a commercial fishery[6] already exists, was primarily designed to test the feasibility of the American west coast live-bait methods and gear in that area.

Previous to the POFI explorations several attempts were made to prospect for tuna in the central Pacific area. In 1948 the Oregon, sent out by the Pacific Exploration Company, caught very few

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6/ During 1950, an average year, approximately 9,500,000 pounds of skipjack were caught. The record postwar catch was made in 1951, when approximately 12,926,000 pounds of skipjack were caught. (A catch limitation was in effect during the last 3 weeks of the 1951 season.)

tuna at the Line Islands (Smith and Schaefer 1949) and only 186 tuna, mostly skipjack, in the vicinity of the Hawaiian Islands (Eckles 1949). The commercial tuna clipper Calistar[7], fishing in the vicinity of the Line Islands during February of 1949, caught approximately 50 tons of yellowfin at Fanning Island and another 15 tons of yellowfin at Palmyra Island. The Pioneer, during the latter part of 1947, caught 7 tons of yellowfin, mostly around Fanning and Christmas islands. During January and February of 1953 the Tradewind caught 7 tons of yellowfin at Palmyra Island and another 6-1/2 tons at Fanning Island.

The results of live-bait fishing in the central Pacific, as conducted by POFI (table 2), indicate that the most promising unexploited area in the central Pacific is the Line Islands, where less time spent scouting and fishing for tuna resulted in the greatest catch. Furthermore, practically all of the catch from the Line Islands was the more desirable yellowfin tuna (see table 3). The Phoenix Islands area, where the bulk of the catch is also yellowfin, appears less promising. The Hawaiian Islands catch is almost all skipjack, with only a very small amount of yellowfin caught. There are not enough data available to evaluate the leeward Hawaiian Islands.

There are other factors besides the total tuna catch which indicate that the Line Islands is the most promising area for future expansion. A greater percentage of the fish schools sighted there exhibited behavior that permitted the vessel to get into a chumming position. Furthermore, nearly 50 percent of the schools chummed at the Line Islands yielded fish, as compared with 23 percent and 32 percent for the Phoenix and Hawaiian islands respectively (table 2). Consistently greater catches of tuna were made from each individual school at the Line Islands. On the other hand, there were more schools of fish seen per unit time of fishing and scouting at the Phoenix Islands than at the other two areas, but only a relatively small proportion of these could be fished. Another factor favoring the Line Islands area is its relative proximity to the Hawaiian Islands. Palmyra Island is approximately 960 miles from Honolulu.

LOCATING SCHOOLS

The majority of the tuna schools were located through their association with flocks of birds. Only on rare occasions were the schools sighted by POFI vessels located by "breezing" or

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7/ The Calistar baited up with 1,800 scoops of anchovetas from Magdalena Bay, Lower California, before going to the Line Islands.

Table 2.--Summary of the results of POFI live-bait fishing for tunas in the central Pacific.

Locality	Date	Number of hours fishing and scouting		Number of fish schools seen	Number of fish schools chummed	Number of tuna schools fished	Actual time spent fishing		Number of tuna caught	Total weight of tuna caught	Number of times sharks interfered
		hrs.	min.				hrs.	min.		tons	
Line Islands											
Kingman Reef	Aug. 1950	11	20	3	3	1	0	13	13	0.13	1
Kingman Reef	May 1951	17	00	15	13	6	2	05	1,008	11.75	3
Palmyra I.	June 1951	3	50	6	5	2	0	05	22	0.25	1
Washington I.	June 1951	15	05	8	7	2	0	33	191	2.62	3
Fanning I.	June 1951	5	05	4	4	4	0	34	327	4.09	0
Christmas I.	June 1951	9	00	3	3	2	1	07	970	10.46	1
Jarvis I.	June 1951	3	00	3	1	1	0	27	10	0.15	1
Total		64	20	42	36	18	5	04	2,541	29.45	10
Phoenix Islands											
Canton I.	Feb. 1950	15	40	12	6	2	?	?	14	0.21	0
Enderbury I.	Feb. 1950	9	40	11	0	0	0	0	0	0	0
Hull I.	Feb. 1950	6	50	7	2	0	0	0	0	0	0
Canton I.	July 1950	28	30	24	17	1	0	10	9	0.10	0
Canton I.	Aug. 1950	10	10	5	5	0	0	0	0	0	0
Hull I.	Aug. 1950	2	30	2	2	0	0	0	0	0	0
Enderbury I.	Aug. 1950	22	40	11	10	4	0	12	162	0.80	0
Birnie I.	Aug. 1950	9	50	8	7	3	0	25	83	1.00	3
Birnie I.	June 1951	2	25	1	1	1	0	25	121	1.51	0
Canton I.	June 1951	8	40	3	2	2	0	31	54	1.57	1
Gardner I.	June 1951	4	50	3	3	0	0	0	0	0	0
Hull I.	June 1951	2	05	1	1	1	0	07	2	0.02	0
Sidney I.	June 1951	5	15	4	4	0	0	0	0	0	0
Total		129	05	92	60	14	1	50	445	5.21	4
Main Hawaiian Islands											
Hawaii I.	Dec. 1949	7	30	3	2	0	0	0	0	0	0
Oahu I.	May 1950	23	10	7	6	1	0	25	35	0.12	0
Maui I.	May 1950	13	00	4	4	3	1	00	20	0.08	0
Kauai I.	May 1950	8	20	2	2	0	0	0	0	0	0
Niihau I.	May 1950	9	00	1	1	1	0	30	6	0.02	0
Niihau I.	June 1950	9	00	2	2	1	0	30	100	0.35	0
Hawaii I.	June 1950	40	50	7	5	1	0	35	12	0.04	1
Total		110	50	26	22	7	3	00	173	0.61	1
Leeward Hawaiian Is.											
French Frigate Sh.	May 1950	6	40	2	2	0	0	0	0	0	0
Midway I.	May 1951	4	30	3	3	0	0	0	0	0	0
Total		11	10	5	5	0	0	0	0	0	0

Table 3.--Weight (in tons) of the tuna caught with live-bait by species and areas.

Locality	Yellowfin	Skipjack	Total tuna
Line Is.	29.31	0.14	29.45
Phoenix Is.	5.06	0.15	5.21
Main Hawaiian Is.	0.02	0.59	0.61
Leeward Hawaiian Is.	0	0	0.0

Table 4.--The distribution of tuna schools fished with live-bait by POFI vessels at the Line and Phoenix islands in relation to the distance from land and the prevailing direction of the wind.

Locality	Distance from reef or shore	Amount of tuna caught (tons)	
		Leeward Side	Windward Side
Line Islands			
Kingman Reef	Within 1/2 mile	11.30	0.01
Kingman Reef	Between 1-3 miles	0.57	0
Palmyra I.	Between 1-3 miles	0.25	0
Washington I.	Within 1/2 mile	0.12	2.50
Fanning I.	Within 1/2 mile	3.04	0
Fanning I.	Between 1-3 miles	0.64	0
Fanning I.	4 miles	0.41	0
Christmas I.	7-1/2 miles	3.04	0
Christmas I.	11 miles	7.42	0
Jarvis I.	Within 1/2 mile	0.15	0
Total:		26.94	2.51
Phoenix Islands			
Canton I.	Between 1-3 miles	0.78	0.10
Canton I.	3-1/2 miles	1.00	0
Enderbury I.	Within 1/2 mile	0	0.80
Hull I.	Within 1/2 mile	0	0.02
Birnie I.	Within 1/2 mile	2.45	0.01
Birnie I.	Between 1-3 miles	0.05	0
Total:		4.28	0.93

"jumping" fish[8/], or by the presence of porpoise with the schools. At the Line and Phoenix islands a number of schools were located by trolling. When a strike occurred, bait was broadcast to bring the school up to the vessel. This method was used extensively by the Tradewind and Calistar during their exploratory cruises to the Line Islands.

LOCATIONS OF THE MORE PRODUCTIVE AREAS AROUND THE LINE AND PHOENIX ISLANDS

In the vicinity of the Line and Phoenix islands 91 percent and 82 percent by weight respectively of the tuna taken by POFI live-bait vessels were caught on the leeward side of the islands. Furthermore, 63 percent and 81 percent by weight of the tuna caught with live-bait in the Line and Phoenix islands respectively have been caught within 3 miles of the reef or shore. These percentages may be slightly biased because there was a tendency to work the inshore and the lee waters of the islands longer and more often since generally more fish schools were seen and caught there, and the weather was more favorable. POFI trolling results also indicate that yellowfin tuna in the Line Islands are more abundant on the lee side of the islands than on their windward sides (see Bates 1950).

SIZE OF FISH

Most of the yellowfin caught by the live-bait method at the Line and Phoenix islands consist of fish weighing between 20 to 30 pounds (fig. 3). These are normally caught on a one-pole rig. Generally, these smaller one-pole fish are the first to take the hooks, and later the larger, deeper-swimming ones will come to the surface and begin biting (fig. 4). These mixed-size schools occur very commonly in the close proximity of the islands of the Line and Phoenix areas. The non-uniformity in size of the yellowfin makes the fishing difficult and hazardous, and often prevents a good catch from being made.

SEASONAL VARIATIONS

Seasonal variation in the abundance of tuna in the Line and Phoenix islands may exist, but our fishing data at present are

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8/ "Breezing" occurs when the school swims close to the surface and causes the water to have the appearance of a tide rip or wind disturbance. "Jumping schools" are characterized by occasional fish jumping out of the water.

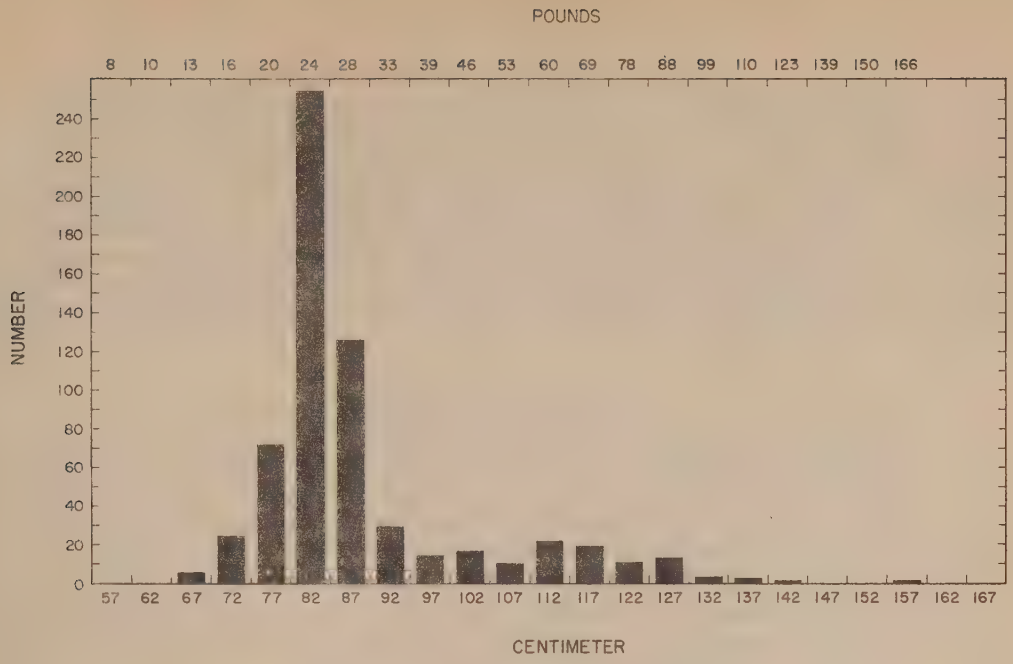

FIG. 3. SIZE FREQUENCY DISTRIBUTION OF SAMPLES OF YELLOWFIN TUNA TAKEN BY THE LIVE-BAIT METHOD AT THE LINE AND PHOENIX ISLANDS DURING MAY AND JUNE OF 1951 BY THE HUGH M SMITH.

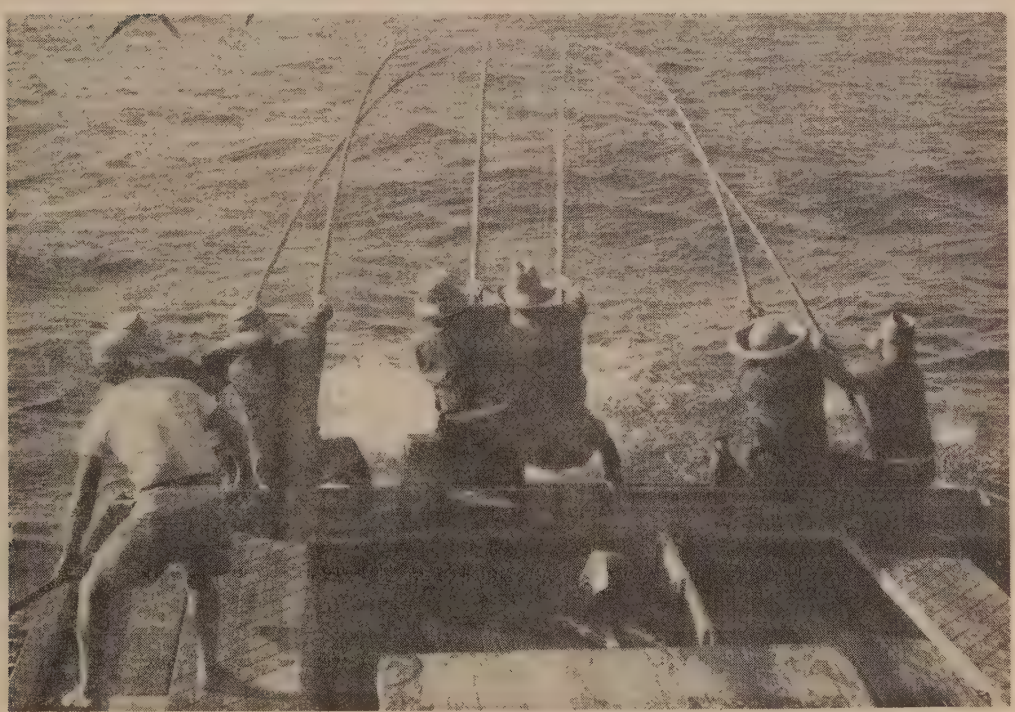

FIG 4. SIX-POLE FISHING AT THE LINE ISLANDS DURING JANUARY AND FEBRUARY 1953 ABOARD THE TRADEWIND.

neither numerous enough nor well enough distributed throughout the year to permit formulation of conclusions concerning seasonality. In the Hawaiian area the skipjack exhibit marked seasonal fluctuations, with the bulk of the catch made during the summer months (Matsumoto 1952). Fishing by the Oregon, Calistar, and Tradewind indicates that at least moderate supplies of yellowfin are available at the Line Islands during the Hawaiian off-season (northern winter). Fishing by the Smith and O'Malley at the Line Islands during the Hawaiian season (northern summer) indicate that the yellowfin are also available during that period.

THE SHARK PROBLEM

In the vicinity of the Line Islands the working of 10 of the 36 schools for which we have records was hampered by sharks. In most instances the tuna were beginning to take chum and were being caught and brought aboard the vessel when the sharks moved in, causing the tuna to become wary. This either forced a cessation of fishing or reduced the catch. There is little doubt that the tuna catch from this area can be increased if means can be found to eliminate or discourage interference by the sharks.

Possibly related to the shark problem is the belief of some fishermen that the tuna shy away from the vessel after a few fish have been hooked and their blood has washed into the water. It may be that the tuna blood is a repellent or more likely that the tuna associate bloody water with sharks. Cleaver and Shimada (1950) report that the Japanese live-bait fishermen stop the deck scuppers "..... with rags and waste to prevent blood from dripping into the water and discouraging fish from biting."

DISCUSSION

The limited number of observations on hand at the present time indicate that live-bait fishing at the Line Islands is fairly good but not as highly productive as off the American west coast. The Smith and O'Malley fishing at the Line Islands during May, June, and August were able to catch tuna at the rate of 29.45 tons to 64.3 hours of scouting and fishing. At this rate, it would take approximately 43 days of scouting and fishing to catch a 200-ton load. This does not include the time spent baiting or the time spent traveling to and from the Line Islands. By way of comparison, in the West Coast live-bait tuna fishery it takes approximately 7 to 8 weeks (Godsil 1938) for the clippers to come back to their home port with a load of tuna[9/]. This total time includes the time spent baiting, traveling to

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9/ A load is estimated as approximately 200 tons. This is a rough estimate derived from figures quoted in the Pacific Fisherman during the fall of 1951.

and from the fishing grounds, and fishing. The best catch experienced by POFI vessels in a single day's fishing at the Line Islands was approximately 10.46 tons, mostly yellowfin, caught off Christmas Island by the Hugh M. Smith in June 1951, whereas in the West Coast fishery, Godsil (1938) writes, "On an average trip, a crew will count upon two or three 'good' days of fishing with a daily catch of 20 to 50 tons." However, he further states that, "It is far more common to get a ton or two from the first attack into a fresh school, with returns dwindling upon each successive try."

A comparison of the catch rates of the Hawaiian commercial fishery with the Line Island rates made by the Smith, O'Malley, and Tradewind indicates that on the average live-bait fishing for tuna is better in the Line Islands, although higher catch rates are recorded on occasion at Hawaii. During the 1950 Hawaiian skipjack season, the sampans caught on the average 2.1 tons of skipjack per boat per fishing day. The tuna clippers Smith and O'Malley fishing in the Line Islands during the summer months of 1950 and 1951 were able to catch approximately 4.58 tons, mostly of yellowfin tuna, per 10 hours of actual scouting and fishing. The 4.58 tons average surpasses the average catch per boat per day even during the peak month of the 1950 Hawaiian season. (The average catch per boat per day during the peak month was 3.7 tons.) During the 1950 Hawaiian skipjack season the best catch made by a single boat in one day was approximately 18.5 tons and that of the 1951 season (a very good season) was approximately 25.0 tons. The best day's catch experienced in the Line Islands was 10.46 tons.

The catch rate of the sampan Tradewind during January and February 1953 was not as good as those of the Smith and O'Malley. There are factors such as seasonality which may have caused this difference in the catch rates. The Tradewind caught 13-1/2 tons of yellowfin in 71.9 hours of actual fishing and scouting. This amounts to approximately 1.9 tons of tuna per 10 hours, a figure which, made during the Hawaiian off-season, compares well with the 2.1-ton average per boat per day of the 1950 Hawaiian season.

The results of the explorations by the Smith, O'Malley, Pioneer, and Calistar have shown that the tuna in the central Pacific can be caught by tuna clippers. Although fair catches were made, most observers question whether the clipper is the most efficient vessel to use in harvesting these tuna. The moderately rough seas which occur quite frequently in this area make fishing from the side racks of a tuna clipper very difficult. Furthermore, the rapid and erratic actions of the fish indicate that a faster and more highly maneuverable vessel than the 100- or 128-foot clippers used in these investigations would be more desirable. Bait is also not available in the central Pacific area in the quantity that a tuna-clipper fleet requires.

The sampan type of vessel appears to be the best suited for this area, although it also has some shortcomings. In the

Hawaiian live-bait fishery the sampan is used almost exclusively. Fishing on these vessels can be done in moderately rough seas without difficulty. These sampans are small compared to the tuna clippers and stay out for only a few days at the most. They have the speed and maneuverability to cope with the "wild" central Pacific tuna, but because of their small carrying capacity and limited cruising range, they are suitable only when operating near their home base. If fishing is to be done in such distant areas as the Phoenix or Line islands, problems of fueling and carrying a paying load of fish have to be solved. This may be accomplished either by building boats with the performance characteristics of sampans but self-contained logistically, or through the use of motherships or bases on the islands.

CONCLUSIONS

1. Observations on the reactions, characteristics, and availability of the different species of bait fish indicate that the best all-around baits are the iao (silverside) and the aholehole (mountain bass). They are both available at the leeward Hawaiian Islands in fair to large quantities, behave favorably when used as chum, and can stand long-distance transportation. Small mullet are also valuable bait fish. They can stand long-distance transportation, attract tuna when they are in good condition, and are one of the most common fish in the Line and Phoenix islands. The nehu (Hawaiian anchovy) and piha (small round herring), which are very good tuna bait, are both too delicate to endure long-distance transportation, and to date have not been found in sufficient quantities either at the Line or Phoenix islands. The goatfish and mollies both were observed to behave in a manner not conducive to good live-bait fishing.

2. The present results indicate that the best baiting ground in the central Pacific is at the main Hawaiian Islands, where the commercial fleet appears to be utilizing the bait stocks nearly to the limit. The best area for future expansion of the baiting grounds appears to be the leeward islands of the Hawaiian group, especially Midway Island. French Frigate Shoals may be another good baiting site, but to date bait has been caught there only in erratically varying quantities. The Phoenix and Line islands, the area showing the most promise with regard to the yellowfin catch, have less bait than the leeward Hawaiian Islands. Possibly with the development of gear and techniques for baiting in very shallow water and with complete surveys of the various lagoons, particularly those of Christmas and Fanning islands, ample supplies of bait will be found for a limited fleet of small vessels. It must be realized that the leeward Hawaiian, Line, and Phoenix areas are as yet relatively unexploited and the amount of fishing pressure that the bait stocks can stand is not known.

3. Yellowfin tuna may be caught by the live-bait method at the Line Islands throughout most of the year, although the fishing to date has not been as productive as that of the American west coast. Nevertheless, fishing at the Line Islands during the winter is good compared to that of Hawaii, which usually comes almost to a standstill at this time of the year. The fishing during the summer at the Line Islands appears to be better than that at the Hawaiian Islands during the skipjack season. Fishing at the Line and Phoenix islands seems to be best within 3 miles of the reefs and shore and in the lee of the islands.

4. The live-bait catch at the Line and Phoenix islands is predominantly yellowfin tuna and that of the Hawaiian Islands is skipjack.

5. Because of the wild and erratic actions of the central Pacific tuna, the necessity of fishing in moderate to rough seas, and the lack of sufficient bait for clipper-type operations, the tuna clipper does not appear to be the most efficient vessel to use in that region. What is required is a vessel that is fast and highly maneuverable but suitable for fishing in fairly rough seas. The sampans used in the Hawaiian fishery are capable of coping with the above conditions, but their short cruising range and small carrying capacity prevent them from going far from their bases.

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